Development, Energy & *Environment*

Amulya Kumar N. Reddy

Parisar Annual Lecture 1990

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Let us start with two general points before we discuss energy. The first point is that our first priority should be development and that energy should come into the picture later as a powerful instrument of development. Such a perspective begs the question: what is development?

For almost fifteen years, I have proceeded with a very simple picture of development that has stood the test of time - development is a socio-economic process directed towards three objectives. The first of these objectives is the satisfaction of the basic needs, starting with the needs of the neediest in order to avoid starting off with satisfying the needs of the affluent. The second objective is to strengthen self-reliance so that people take control over their own destinies. Otherwise, a dictator can satisfy the basic needs of the people without allowing them to have any say over their future, and call the process development. And the third objective is that the development process must be sustainable if it is to withstand the passage of time and survive over the long run, and if it is to be sustainable, then the development process has to be in harmony with the environment.

The second general point is that we are in the midst of what Thomas Kuhn, the Harvard philosopher, called a "paradigm revolution". I am sure that all of you know this word "paradigm". I began to understand it only when I realized that it was analogous to the "raga" of Indian classical music. A raga is a framework or pattern. Anybody who sings and plays an instrument in that raga has to adhere to its framework and pattern, but within the constraints of that framework and pattern, the musician can extemporize to any extent that she or he wants. Thomas Kuhn pointed out that,

at any period in history, there is a particular paradigm that prevails - this is the ruling paradigm and everybody thinks within the constraints of that paradigm. The paradigm works for a period, but gradually a stage is reached when its tenability decreases. Its effectiveness diminishes and it begins to break down. Then, a paradigm revolution takes place and a new paradigm comes into being. It is like changing over from one raga to another raga.

The relevance of all this to our present discussion is that there is at present a prevailing paradigm on energy that dominates virtually all energy thinking in the country. This paradigm dominates the views of the Government, the approach of the official planners, and the thinking of most people on the subject of energy.

Conventional Paradigm for Energy Planning

DEVELOPMENT = GROWTH = ENERGY = ELECTRICITY
= CENTRALIZED GENERATION + GRID T & D

DEVELOPMENT = GROWTH = ENERGY = OIL =
ENGINES / FURNACES / TURBINES / FUELLED WITH
PETROLEUM DERIVATIVES

Figure 1

The conventional paradigm for energy planning is shown in Figure 1. At the outset, the conventional paradigm equates development with economic growth which is measured by the magnitude of the Gross Domestic Product (GDP). Then, the paradigm states that the only way we can increase growth is by pumping more energy into the economy. So, we are asked to think in terms of energy consumption as a necessary condition for economic growth. Then, the paradigm moves on to electricity and so on and so forth.

Conventional Supply Based Paradigm

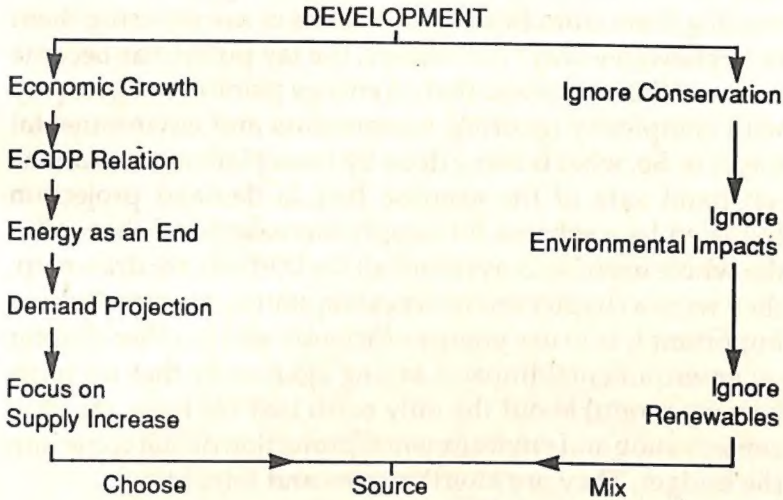


Figure 2

I want to amplify this point by drawing your attention to the left of Figure 2. The conventional paradigm or pattern of thinking says that if we want development, then we have to have economic growth, and if we want to increase GDP, we must increase energy consumption (this is the so-called Energy-GDP relationship!). So energy becomes an end in itself and once energy becomes an end in itself, our main task is to answer the question: how much energy will be required in the future, say in the year 2000 or 2020?, i.e. we must make a *demand projection*. Once we make the demand projection, then we must start thinking about how we can increase the supply of energy to meet that demand. We must identify various energy sources to meet that demand.

On the right hand side of Figure 2, I have pointed out all the things that have been forgotten in this consumption-directed supply-biased process of energy planning. We have forgotten the possibility of saving energy and of using energy more efficiently. We have completely forgotten about

the environmental impacts and we have forgotten about whether the sources of energy that we are using are renewable or non-renewable. Are we depleting them? Are we stealing them from future generations or are we using them in a renewable way? Nowadays, the lay public has become aware of these issues so that no energy planner can get away with completely ignoring conservation and environmental impacts. So, what is being done by most planners is to do the left hand side of the exercise first (a demand projection followed by a scheme for supply increases) and then, after the whole exercise is over and all the budgets are drawn up, they write a chapter on conservation stating powerfully how important it is to use energy efficiently and another chapter on environmental impacts saying eloquently that we must be very careful about the only earth that we have, etc. But, conservation and environmental protection do not come into the budget. They are afterthoughts and retrofits.

This is the conventional paradigm on energy — we shall call it the GRowth-Oriented Supply-Sided CONsumption-directed paradigm for which the acronym is GROSSCON — according to the Oxford dictionary, "gross" means *flagrant* and "con" means *confidence trick*. If, for the next few months, you scrutinize every statement on energy that is made by our ministers and planners, you are bound to find that all those statements illustrate this GROSSCON paradigm. What are the consequences of using this paradigm? Consider the case of Karnataka.

Figure 3

A few years ago, the Government of Karnataka appointed a Committee for the Long Range Planning of Power Projects (which we shall call the LRPPP Committee). This Committee submitted its report in 1987 in which it argued that, in the year 2000, Karnataka would require 47.5 terawatt Hours (1 TWh = 1 billion kilowatt hours = 1000 million units = 10^{12} kWh), i.e., about 6.2 times the approximately 7.6 TWh used in Karnataka in 1986.

LRPPP Projection

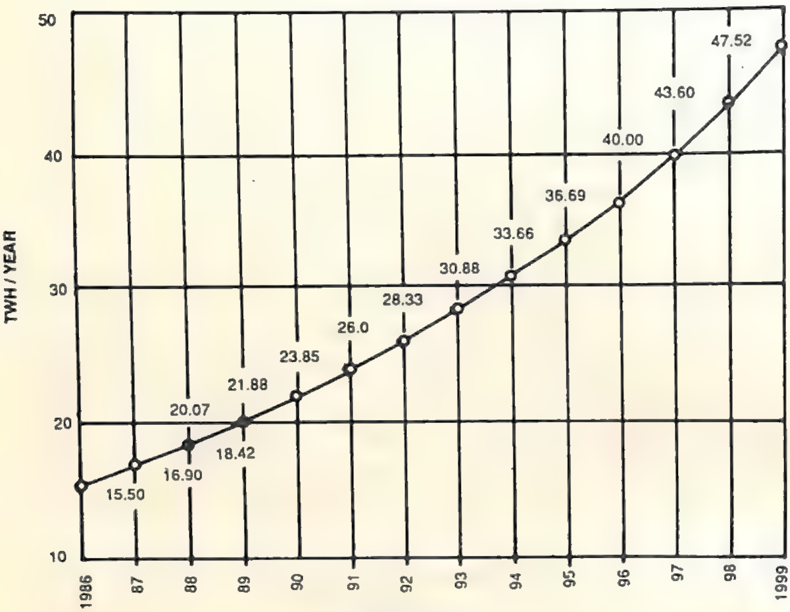


Figure 4

The interesting thing about demand projections in India is that nobody questions them. In fact, this only illustrates the point made by Hitler's Propaganda Minister Goebbels who said that if a lie is repeated a thousand times, in the end, the people will believe it. The statement about the amount of energy that will be required in the year 2000 to 2020 is constantly repeated by the Government spokesmen. But nobody goes into the question of how they arrived at their numbers - unless you happen to be an academic who is outside this whole Government exercise and says "I am sorry, I cannot accept any number unless I calculate it myself on my calculator". Then, it turns out that what the LRPPP Committee has done is really a school exercise. They have used a 9% compound rate of growth, so that if the energy demand is 15.5 in the year 1986, the demand will grow from the 1986 value to 47.5 in the year 2000. So there is no magic or mystery and no great planning achievement; this is

something any schoolboy or schoolgirl can do. Now recall the conventional paradigm: energy is an end in itself, we must first make a demand projection, and once this demand projection is made, then we start thinking about the supplies that will meet that energy demand.

Implications of LRPPP

1. Infrastructure development (T&D Lines, Coal Linkages, Expansion of rail facilities etc.)
2. Massive Centralized Power Generation
   (a) 1,000 MW Super-Thermal Plant
   (b) First, 2 x 235 MW Nuclear Plant at Kaiga
       then, 2,000 MW in XI Plan
3. Rs. 25,000 Crores ($ 16.6 Billion @ Rs. 15/$)
4. Aid from Central Government
5. Aid from World Bank
6. More than 25% jof State Plan for Power
7. Private Industry to set up generation facilities

Figure 5

What are the implications of this LRPPP projection? Firstly, we have to develop our infrastructure by a tremendous amount. We have to have transmission and distribution lines and coal linkages; we must expand our rail facilities. We must set up massive centralized power generation — a 1000 MW superthermal power plant and about 2000 MW of nuclear power. When there is a growing popular environmental movement complaining about the first two reactors, the LRPPP projection is asking for six more. Finally, there is a "small" bill of Rs. 25,000 crores ($ 16.6 billion @ Rs. 15/$) presented by the LRPPP Committee. How does this Committee expect the Karnataka Government to raise this Rs. 25,000 crores ($ 16.6 billion)? Well, the Karnataka Government is supposed to get aid from the Central Government and from the World Bank, to set aside more than 25% of the State's plan for power and when all this is inadequate, to turn to the private sector and request them to set up generation facilities. Supposing the government is able to do all this, what does the projection promise us?

Promised Benefit
"....... ENERGY SHORTAGES WILL CONTINUE UP TO, AND EVEN IN, 1999-2000 A.D., WITH LITTLE HOPE THEREAFTER."

Figure 6

Figure 6 says ..."that energy shortages will continue up to and even in the year 2000, with very little hope thereafter...". This is an actual quotation from the LRPPP Report and it illustrates very well what is wrong with the conventional paradigm - it offers us gloom and despair; it offers us very little hope.

Let us now summarize all the sins of the conventional paradigm.

Seven Sins

1. Unwise-------------------- > Emphasises Consumption Not Services
2. Unfair--------------------- > Poor are Bypassed
3. Unclear------------------ > Opaque
4. Unfrugal------------------ > Efficiency Improvements Ignored
5. Unbalanced------------- > Exclusive Stress on Supply
6. Uneconomic------------ > Exorbitant Requirements on Capital
7. Unsustainable---------- > Negative Environmental Impact

Figure 7

The conventional paradigm is *unwise* because it emphasizes the consumption of energy and not the services that energy provides. None of us wants kilowatt hours, what we want is light, heat, warmth, translational motion in transport, rotating shafts in machinery, etc. So what is important is the *services* that energy provides, and not merely the consumption of energy *per se*. Conventional energy planning is *unfair* because it bypasses the poor.

I am making this complaint of unfairness on the basis of a computation where we computed what percentage of Kar-

nataka's population benefits *directly* from electricity. If we compute the number of electrified homes and multiply that by the number of people in the home; if we multiply the number of factories by the number of workers in the factory, etc., then we will find that *50% of Karnataka's population is bypassed by electricity.* They do not receive direct benefits from electricity and this means that a large part of the population is left out of this whole electricity planning process.

The conventional paradigm commits other sins. It is *unclear* and opaque because it is not easy to find out how the planners arrive at their numbers and projections. It is *unfrugal* (to coin a word) because it ignores efficiency improvements. It is *unbalanced* and supply-biased because it looks only at the supply of energy and not at how this energy is being used i.e. it does not look at the demand side. It is *uneconomical* because it requires exorbitant amounts of capital and finally it is *unsustainable* because of the negative environmental impacts.

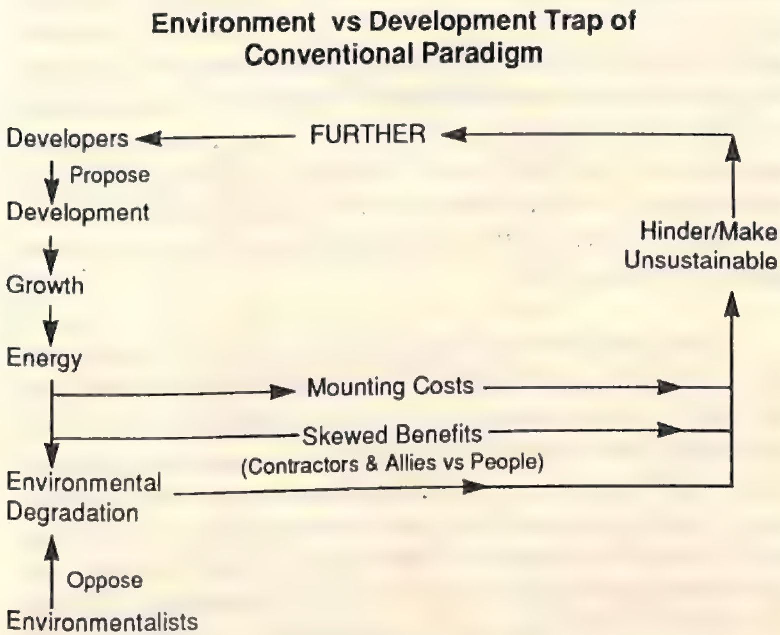


Figure 8

The conventional paradigm for energy is also responsible for landing us in the environmental-development trap that everyone is talking about. Let us start at the top left-hand corner of Figure 8. There are groups of people whom I have called *developers* (I am purposely using a pejorative word!). Now what they propose is their version of "development". In order to achieve their development, they must have economic growth and in order to have economic growth - according to the conventional paradigm - they must have increases of energy consumption. When, however, this energy is produced, there are a number of side effects, but like many modern doctors who prescribe "miracle drugs" without telling patients about the side effects of these drugs, the developers do not tell the people about the side effects of these energy projects. One of the most important of these side effects is environmental degradation. People who see the environment degrading realize that it is going to ruin our entire life-support system, and because they object to this disastrous result, the only way they can prevent this environmental degradation is to oppose the energy projects. Thus, a conflict grows in intensity - the developers say that the environmentalists are preventing development and progress, and the environmentalists say that the developers and planners are destroying the environment making further development impossible and the development process unsustainable. The two sides are locked in battle. This conflict cannot be resolved within the framework of the conventional paradigm (Figure 8).

There are also other side effects two of which offer hope for an alternative paradigm. First of all, there are the *mounting costs*. It is becoming increasingly more and more expensive to generate that energy. Economists say that the marginal cost of power is increasing which means that it is more expensive to produce the next kilowatt than the previous one. That is because as the easy sources get exhausted, we have to turn to the more difficult ones. We have go from the easy dams and mines and oil fields to the remote dams in

mountainous areas, the deep mines and off-shore sources of oil.

Then comes the other dimension of the problem. The people who are located at the site of these development projects become the victims of development and they don't see this process as development at all. They see it as a process whereby a group of people - the contractors and their allies - benefit from these projects whereas they become the displaced victims. This conflict is taking place over the Narmada and other projects. These victims then begin to oppose large energy and other development projects.

So the situation which the conventional paradigm has led us into is one of environmental degradation, mounting costs and conflicts with the people located at the site of the project. We have a situation where each side is accusing the other side. Those who want economic growth accuse environmentalists of opposing the progress of the people and the environmentalists say that developers are ruining the environment.

Electricity Sector

If $E(0)$ = Installed Capacity (GW) in Base Year

g_E = Growth Rate of Capacity

g_G - Growth Rate of GDP

a = (g_E / g_G) =Ratio jof Growth Rates

= GDP Elasticity of Electricity Demand

= ($d \log E / d \log G$)

UCOP = Unit Cost of Power (RS/KW or $ /KW)

Annual investment Required for Capacity Expansion

$= E(O) * a * g_G * UCOP$

$= E(O) * g_E * UCOP$

Figure 9

I would like to elaborate on the issue of these economic costs. At the bottom of Figure 9, you will see a simple formula which indicates how to calculate the annual investment required for the power sector. Now, when this formula is

used - it turns out that what the electricity sector asks for is 3 to 5 times more than it can ever hope to get from the Government. Please note that both the size of the total plan and the percentage of the total plan earmarked for electricity are fixed by the Government - and not by the Electricity Sector! Therefore, the Government, which has a number of other crucial developmental sectors such as education, health, etc., to look after, says that it can make available only so much money to the electricity sector but the latter wants 3 to 5 times that amount. It has been pointed out that, in this conflict, the electricity sector is like the demon Bakasura who had an insatiable appetite; no matter how much he was fed, he always wanted more. The share of the plan going to electricity now has increased from 10% to 15% to 20% to 25% and now the electricity sector wants even more. This then is the economic consequence of the conventional paradigm for energy - what the electricity sector asks for is impossible. Consequently, it is economically impossible to proceed in the manner in which we have been proceeding in the past.

Karnataka's Crisis

IF E(1986) = E(0) = 2.53 GW, gG = 0.05 (5%),
a = 2 & UCOP = Rs. 32,000 / KW ($2,000 / kw).

ANNUAL INVESTMENT REQUIRED FOR ELELCTRICITY SECTOR
= Rs. 810 Crores / Year
= $ 506 Million / Year
= 100 % of Karnataka's Annual Plan

But Electricity Sector Cannot Get > 25% of Plan
hence, allcation for Electricity < Rs. 275 Crores / Year
or $ 172 Million / Year = 34% (One-Third)of "Reqt"

Figure 10

In the case of Karnataka, what the Electricity Sector is asking for is Rs. 810 crores ($ 506 million) per year (Figure 10) which is almost the total budget of the Karnataka Plan, while the amount allocated to the Electricity Sector is not more than 25% of the Plan which is about Rs. 275 crores ($ 172 million).

Therefore, only one-third of the electricity sector's requirement can be provided. Is there a solution to this fundamental economic conflict?

Solution to Karnataka's Crisis

Hence Karnataka must abandon Conventional (**a** * UCOP)
= (2 * Rs. 32,000 / KW) = (2 * $ 2,000 / KW)

If **a** is retained, then UCOP (including T & D) must be reducedvia cheaper generation technologies to
<< Rs. 32,000 /KW or << $ 2,000 /KW,

or if UCOP & gG = 5% are retained, then **a** < 2
(Greater GDP Productivity of Electricity)

Figure 11

I believe that there is (Figure 11). Without going into the details, the solution is to lay more emphasis on efficiency improvements (smaller values of **a**, so that for the same inputs of energy we can achieve greater increases of GDP - "more GDP bang for a smaller energy buck" as the Americans would say. Another solution is to opt for cheaper sources of power so that the Unit Cost of Power (Rs/KW) is decreased.

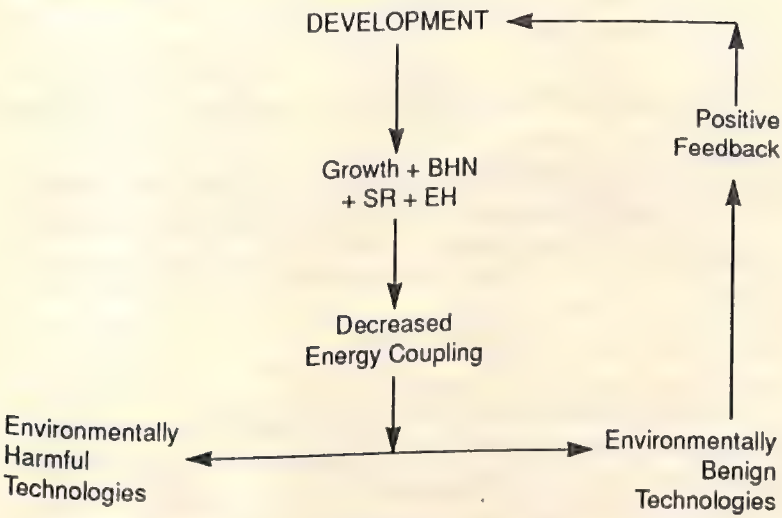
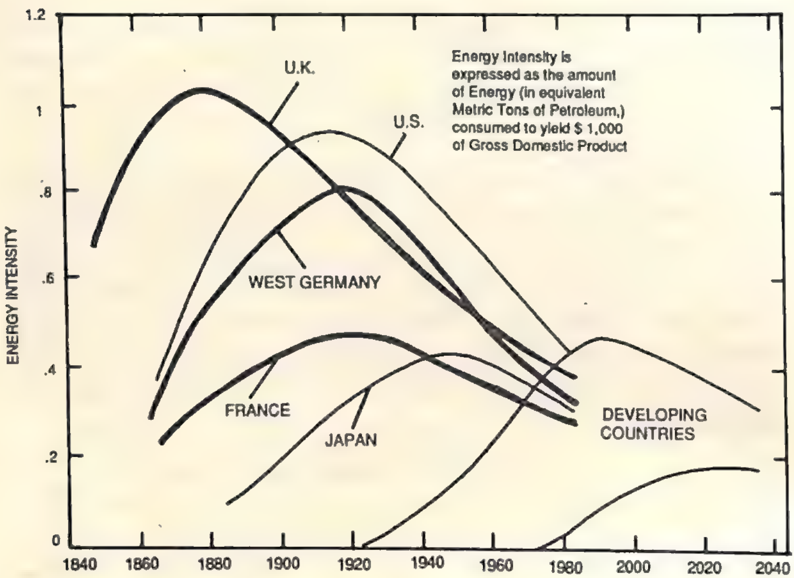


Figure 12

What we are asking for (Figure 12) is a decrease of the coupling between Energy and the GDP, so that with less energy we can get more economic growth.

Is there any historical evidence for a decrease in energy intensity, i.e., the energy required per unit of GDP output? In fact, there is! When the energy intensities for the past century are plotted for a number of countries, interesting plots are obtained.



In Industrialized Countries the energy intensity (ratio of energy consumption to gross domestic product) rose, then fell. Because of improvements in materials science and energy efficiency, the maxima reached by countries during industrialization have progressively decreased over time. Developing nations can avoid repeating the history of the industrialized world by using energy efficiently.

Figure 12A

As seen from Figure 12A, every industrialized country shows an increase of energy intensity during the period of industrialization, a maximum and then a decrease in the energy intensity during the post-industrialization phase.

The rise during industrialization is because large quantities of basic materials (steel, cement, non-ferrous metals, chemicals, glass, etc.) are required to build the machines, railroads, bridges, roads, buildings, and other infrastructure. Once there is a saturation in the requirements of these basic materials, then all that is required is minimal quantities as replacements.

The second interesting conclusion from Figure 12A is that the more recent the process of indutrialization, the lower is the maximum. This is because of two results of the materials revolution. Firstly, the energy required to produce a unit quantity of a basic material has decreased steadily (for example, the energy required to produce a tonne of steel today by the best technology is much less than what was used 50 or 100 years ago) — processes have become more efficient. Secondly, the quantity of material to perform a given function has also decreased (for example, the steel required to build a bridge is much less than that required in the past) — materials have become more efficient from structural and other points of view.

The third conclusion from Figure 12A is that developing countries should avoid repeating the evolution of the energy systems of the early industrializers like UK and USA. If at all they want to copy the industrialized countries, they should emulate the most modern industrializers like Japan. Better still, because they have not completed building their infrastructures, they should go in for technological leapfrogging and achieve even lower maxima than France and Japan.

Once there is reduced coupling between energy and GDP, we can choose environmentally benign technologies, and if we choose such technologies, then we have a positive feedback on development so that environmental concerns and development objectives need not conflict with each other. They can then work together synergistically and this is what is meant by sustainable development (Figure 12).

Conventional Paradigm

GROSSCON = GRowth- Oriented Supply-Sided CONsumption-deirected

New Paradigm

DFEFENDUS = DEvelopment - Focused END-Use - oriented Service - directed

Figure 13

Is this feasible or is it all a dream? I submit that, in the case of Karnataka, it is not a dream. We have worked out an alternative which I shall now describe briefly. We have called it a DEFENDUS scenario where DEFENDUS is an acronym for Development-Focussed End-Use-oriented Service-directed (Figure 13). It is the only kind of scenario that can *defend us* in the present crisis.

Components of DEFENDUS Electricity Scenario

- Development Focus (via Growth Rates for Connections)
- End-Use Orientation (via Energy Consumption Norms)
- Supply Increase

Figure 14

There are three components to this DEFENDUS paradigm (Figure 14). The first component is the *development-focus* through which we can express our commitment to development. How can we do this? Consider the Electricity Sector. Electricity is consumed by various categories of consumers — domestic homes, low tension industries, high tension industries, the agricultural sector etc. We have to take a view as to whether the present rate of growth of these different categories of consumers is acceptable or whether our development perspective requires us to have a different approach to the growth in the number of connections. For

instance, if we feel unhappy that fifty percent of Karnataka homes do not have electricity, then we can express our development commitment by saying we will increase the rate of growth of connections in the domestic sector. If we feel unhappy that the number of connections of pumpsets is not adequate, then we can increase the rate of growth of pumpsets and so on.

The second component of the DEFENDUS paradigm is the *end-use orientation* and *direction towards energy services* (rather than consumption) where apart from looking at the supply of energy we look at how energy is being used. We must find out the end-uses of electricity and see whether in each of the end-uses the energy is being used efficiently or whether it could be used more efficiently. We must examine the level of services provided by energy, and explore whether more services can be provided with the same or less energy.

Finally, the third component concerns the *supply-mix*, i.e., how energy supplies can be arranged to meet the requirement.

The Development Focus

- Electrification of Homes
- Structural shift to Non-Power-Intensive employment-Generating Industries

Figure 15

Consider the development-focus (Figure 15). In the case of Karnataka, the DEFENDUS scenario envisages the electrification of all homes in Karnataka by the year 2000. The vision is that every single home will have an electricity connection and electric lights instead of kerosene lamps. The second item of the development-focus concerns employment generation. We know that employment generation takes place primarily through the non-power-intensive employment-generating industries — the so called Low Ten-

sion (LT) connections. In other words, the rate of growth of LT connections should be stepped up. The third item is the energization of all pumpsets upto the limit set by the ground-water potential of Karnataka.

The End-Use Orientation	
O	Efficiency Improvements
O	Replacement of Electricity with other sources of heat.
O	Load Management

Figure 16

Consider now, the end-use orientation (Figure 16). What we should try to do is to improve the efficiency of use of electricity, to replace electricity with other sources of heat and to manage our load better.

Augmentation of Electricity Supplies	
O	Reduction of T & D Losses
O	Electricity Congeneration in Sugar Factories
O	Non - Conventional Electricity Supplies (Small Hydel, etc.)
O	Biomass - Based Decentralized Electricity Generation for Villages

Figure 17

Finally, with regard to increase of supply (Figure 17), the first item is obviously a reduction of the transmission and distribution losses. There are also possibilities of electricity supply to the grid from sugar factories. The bagasse which is left after crushing the sugarcane and extracting the juice is currently used as fuel in our sugar factories instead of letting it pile up as waste to be disposed off. This bagasse is deliberately burnt at low efficiency to produce steam and the small amount of electricity required by the sugar factory. But what is happening in Brazil, the Philippines and some other developing countries, is that they are burning the bagasse at higher efficiencies, generating more electricity than the sugar factories require and then exporting the excess electricity to

the grid. So there is a fundamental change of perspective for the sugar factories — electricity becomes (one of) the main products of sugar factories and sugar becomes a by-product. Why is this new perspective important? Even though Karnataka is not the largest sugar producer in the country, if we use the efficient technologies of burning the bagasse that are available today, its 19 sugar factories can export almost as much power as one nuclear reactor of 235 MW which is not a trivial amount.

In addition there are the so-called non-conventional sources of electricity in Karnataka. There are a number of possibilities e.g. small hydel plants and as far as villages are concerned, biomass-based decentralized sources based on biogas and a producer gas which is obtained by combusting wood. So, these are some of the new sources that we are thinking of in the DEFENDUS scenario.

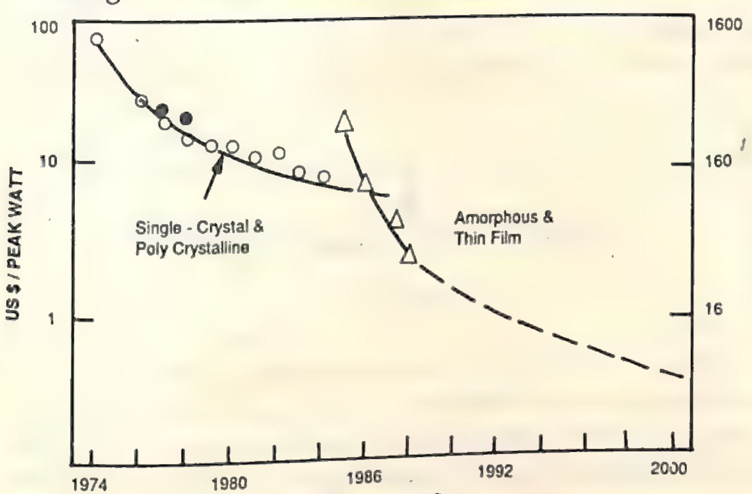


Figure 18

There is also the possibility of *photovoltaic cells* based on amorphous silicon which receive solar energy and convert it into electricity. We have not taken these into account in spite of the fact that the price of these cells is drastically dropping every year (Figure 18) so that somewhere between the year 1995 to 2000 they will become competitive enough to run

pumpsets on and be economically viable. In spite of this promise, we have not considered them in our energy scenarios.

Defendus Energy Requirement Scenario for Year B+J for each End-Use of each Consumer Category

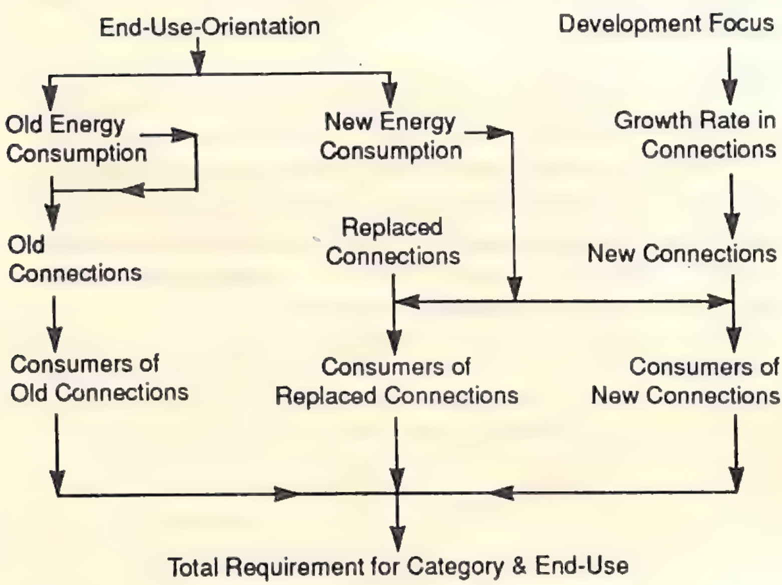


Figure 19

What I have tried to point out in Figure 19 is how we make the actual calculations. I won't go into details but I would like to bring one or two points to your attention. The computer spreadsheet that we use gives you total freedom to choose your own development-focus through the growth rate in connections (at what rate you want the domestic or agricultural connections to grow) and to express your end-use orientation through the energy consumption norm for that end-use, i.e. how many kWh is consumed per connection. So you have two controls — you have a development-focus control and an end-use orientation control. The develop-

ment-focus control is to express your *values* and the end-use focused control to display your *technical knowledge*. The development-focus control involves your heart and the end-use orientation control your head. Of course, in our computer spreadsheet, you can even be heartless and maintain the present trend in the growth of various connections and you can also be mindless and preserve the present inefficiencies. If you are both heartless and mindless, you get what is called a "business as usual" scenario where things are envisaged to go on as at present.

Let us now elaborate on the development-focus, end-use-orientation and supply components of the DEFENDUS scenario for Karnataka.

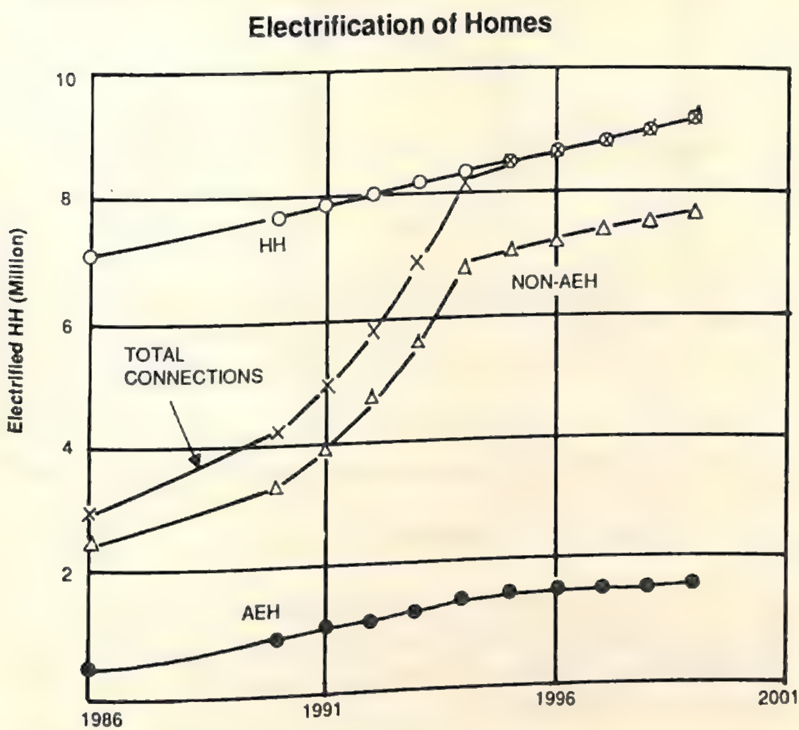


Figure 20

The first element of the evelopment-focus is the *electri-*

fication of homes. The plot at the top of Figure 20 is based on the census and indicates how the number of households in Karnataka is expected to increase, and the two curves at the bottom indicate how the DEFENDUS scenario plans an increase in the number of electrified homes (of the AEH (affluent) and non-AEH (non-affluent) categories) so that they become equal to the total number of homes, i.e. 100% home electrification, by the year 1994-95.

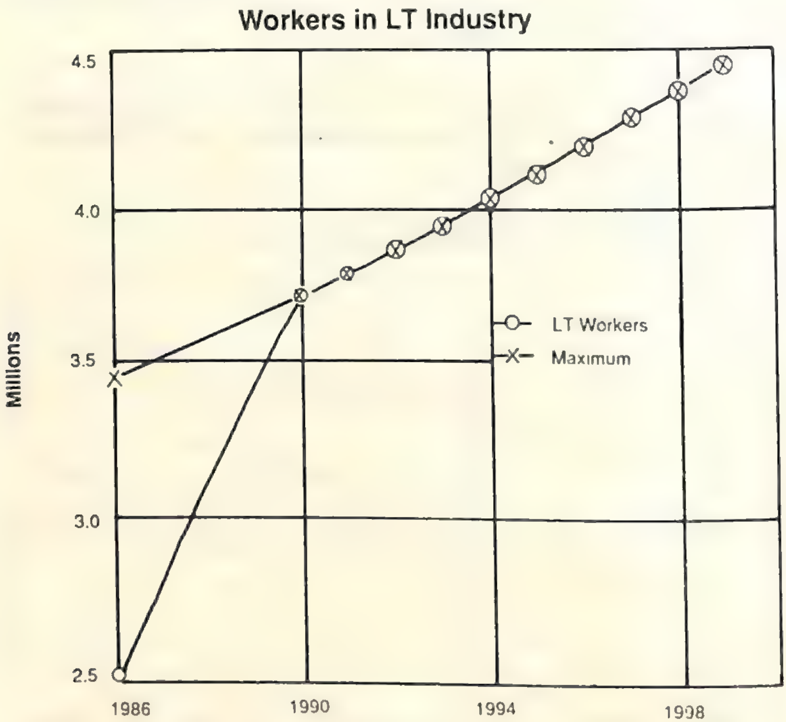


Figure 21

Similarly, it is envisaged that the number of workers in the LT industry will rise to the maximum employable according to the census (Figure 21) in order to reflect our concern over employment.

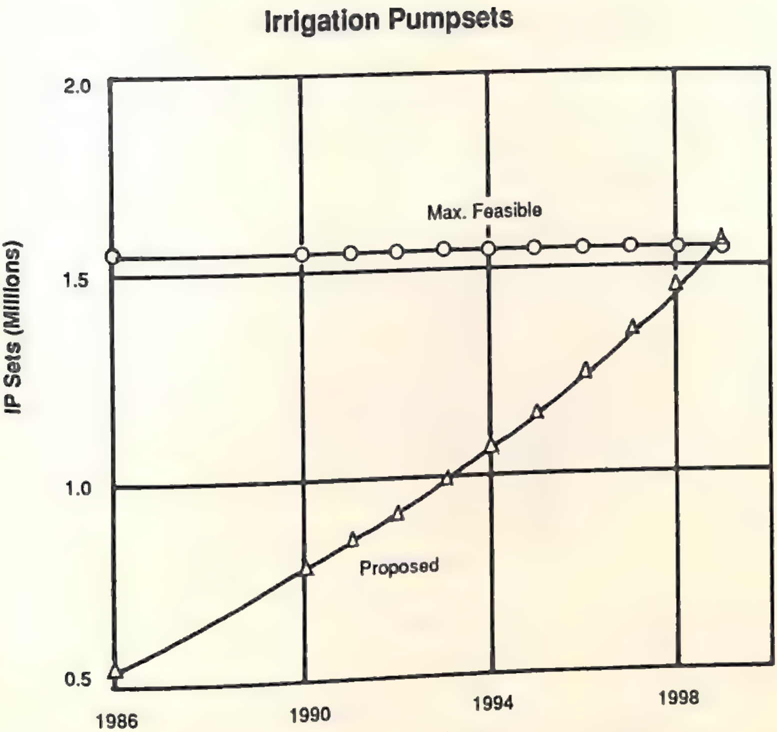


Figure 22

Finally, it is envisaged that the number of irrigation pumpsets will be increased up to the maximum feasible subject to the groundwater potential of the state (Figure 22).

To implement the end-use-orientation of the DEFENDUS scenario, it is first necessary to consider what efficiency improvements should be considered. First, a category-wise analysis of electricity consumption has to be made.

It turns out (Figure 23) that in Karnataka, 45% of the electricity is used by HT industries, 17% for irrigation pumpsets, 17% by All-Electric-Homes (these are the homes of the affluent which have a special tariff for a heating circuit), etc. However, that information on consumption by categories is not enough for scenario construction because we must know what this electricity is being used for - that is what is meant by end-use analysis.

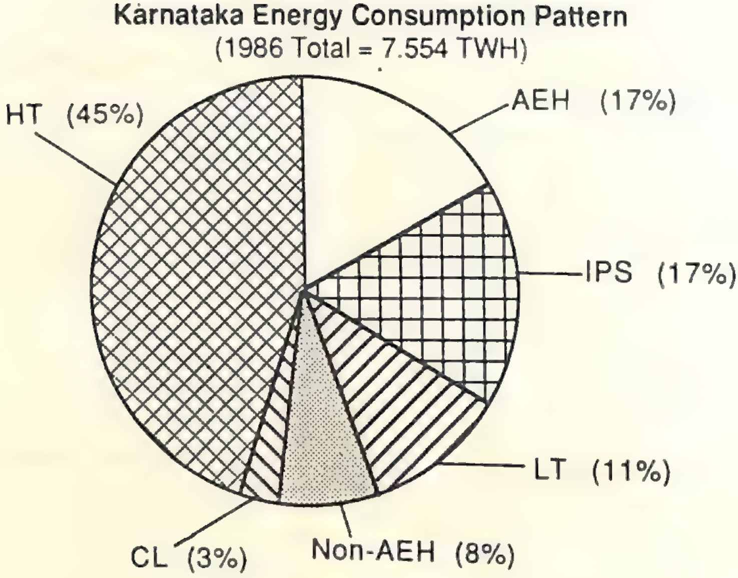


Figure 23

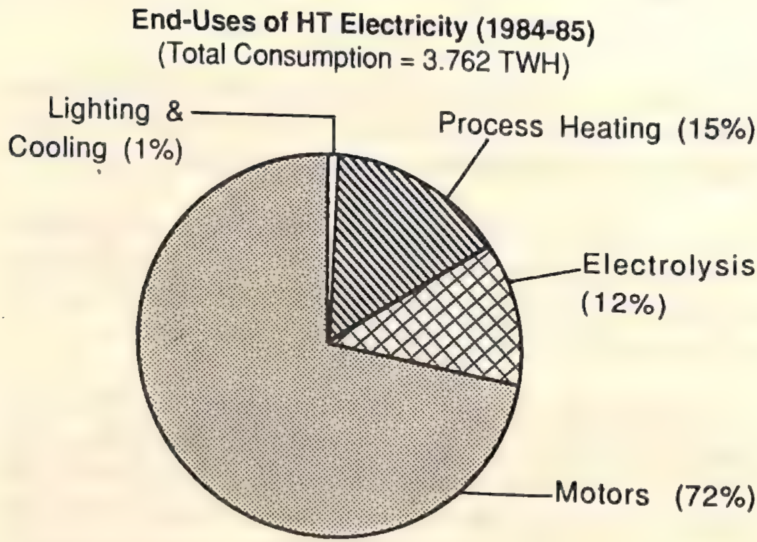


Figure 23A

In the case of HT electricity, it is seen from Figure 23A that 72% is used for motor, 15% for process heating, etc.

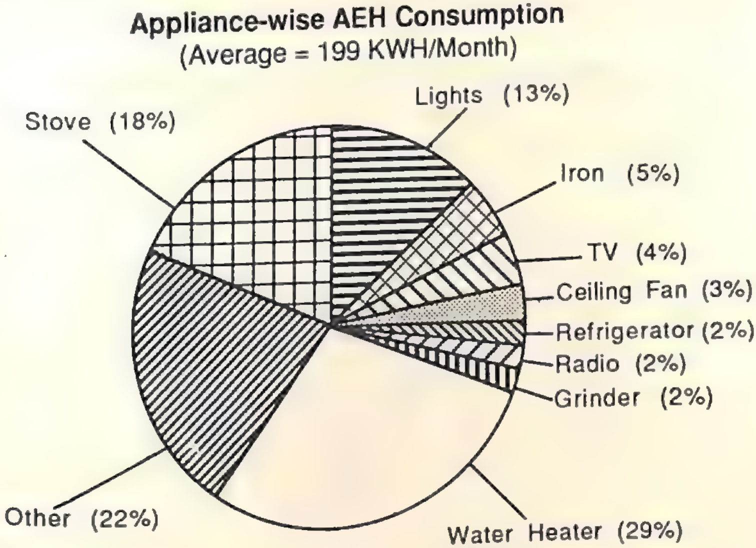


Figure 24

We have also looked into how electricity is being used in homes by disaggregating the electricity consumption by various appliances. This is what you need to know if you want to make policy recommendations regarding electricity consumption. In the case of Bangalore, the capital of Karnataka, the houses of the rich — the All-Electric-Homes (AEH) — consume about 200 kWh per month compared to the 33 kWh of the Non All-Electric-Homes of the average income groups (Figure 24). The incomes are in the order of Rs. 2,500 (about $ 156) per month and above in the case of the former and about Rs. 1,500 (about $ 94) per month in the case of latter. Furthermore, (Figure 24) shows that 29% of the electricity used in the All-Electric-Homes is used for water heating. Please reflect on that fact. Electricity is produced at the huge hydroelectric power station located several hundred kilometres away at Sharavati or Linganmakki, and then transported over hundreds of kilometres over these enormous

transmission and distribution (T & D) lines. And what is this electricity used for? To raise the temperature to about 45°C! Are there not simpler and less expensive ways of doing this? Then, 18% is used for electric cooking, 13% for lights, etc.

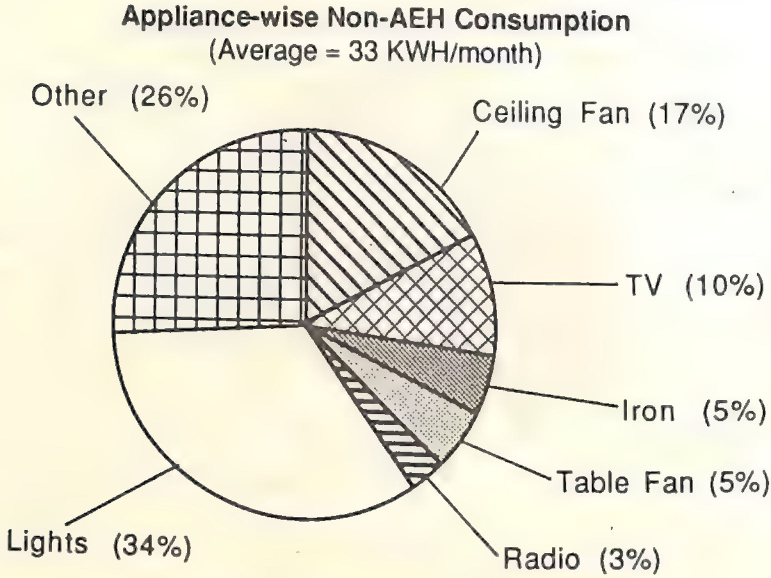


Figure 25

In the case of the Non-All-Electric Homes of the poor, the connections do not permit a water heater (they have an upper limit to how much power can be used). So, 34 % is used for lights, 17% is used for ceiling fans, etc., (Figure 25). Now that we know the main uses of electricity, we must consider the efficiency increases that are likely to make an impact on the energy consumption. After all, there is not much point in achieving efficiency increases in an end-use that does not account for much consumption.

A list of five efficiency improvement and electricity substitution measures have been recommended for the DEFENDUS scenario that we have proposed (Figure 26). These are very simple measures available anywhere in the world today. They are neither futuristic nor of the dream variety.

Efficiency Improvements & Electricity Substitution Measures

- Industrial modernization (efficient drives, furnaces, boilers, etc & new processes)
(Saving --> HT -- 25% & LT -- 15%)
- Replacement of 60 W incandescent bulbs with 15 W compact fluorescent lamps
(Lighting --> Non-AEH -- 58% & AEH 14%)
- Solar Water Heaters (AEH --> 28% for WH)
- LPG instead of electricity for cooking
(AEH --> 18% for cooking)
- Frictionless foot-valves and HDPE piping in irrigation pumpsets
(30% saving in approximately 1800 KWH/Year/IPS)

Figure 26

Firstly, there are *efficient motors* available today which permit a saving in the HT industry of about 25% and in the LT industry of about 15%. Secondly, there are *compact fluorescent lamps* that consume only one-fourth the power of the incandescent bulbs while providing the same amount of light. You will recall that according to the DEFENDUS paradigm, it is the light (measured in lumens) that matters, not the energy consumption for lighting (measured in kWh). If you can achieve the same amount of illumination with a quarter of the energy input, then that is an alternative option that should be seriously considered. Also, we should be interested in these compact fluorescent lamps because lighting plays an important role in both All Electric and Non-All-Electric houses. Thirdly, we should consider introducing *solar water heaters* because it is preposterous that 28% of the scarce and precious electricity used in a home should be used just to heat water for bathing. Solar heaters are available today, so why not incorporate them in the DEFENDUS scenario. In the case of electric cooking, we should think of *LPG cooking* assuming that LPG will be available at least from the 30% of our natural gas that is being flared (burnt) today because we have not built the facilities to use it.

Finally, there are two simple innovations that can reduce drastically the electricity consumption by irrigation

pumpsets in the agricultural sector. One is known as a *friction-less foot-valve,* which prevents the water sucked up by the pump from flowing back. Friction-less foot-valves use very little energy when they open and close. The second innovation involves the replacement of galvanized iron piping (with a very rough inside surface) with *plastic HDPE piping.* These two innovations together involve a total expenditure of about Rs. 1,000 (about $ 62), and permit a saving of about 30% of the electricity which is used by a pumpset. This is a very considerable saving when you consider that in Karnataka there are about half-a-million pumpsets and that these pumpsets consume about 17% of the Karnataka's electricity.

DEFENDUS and LRPPP Scenarios
(Generation)

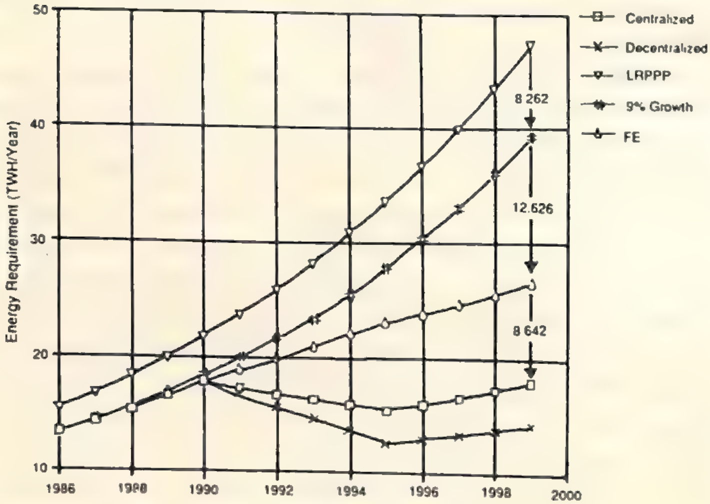


Figure 27

Apart from a reduction of about 8.3 TWh due to differences in the computational procedure and in the base year demand, the net result of the three elements of the development-focus and the five efficiency improvement measures is that instead of the LRPPP projection of 47.5 TWh, the DEFENDUS energy requirement turns out to be only 18.0 TWh (Figure 27).

The reduction of 29.5 TWh achieved by the DEFENDUS scenario with respect to the LRPPP projection is due to a number of factors shown in Figure 27A.

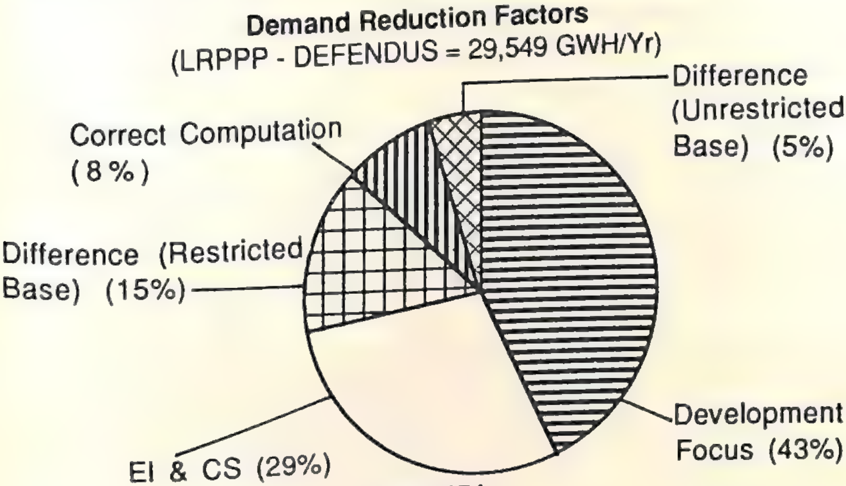


Figure 27A

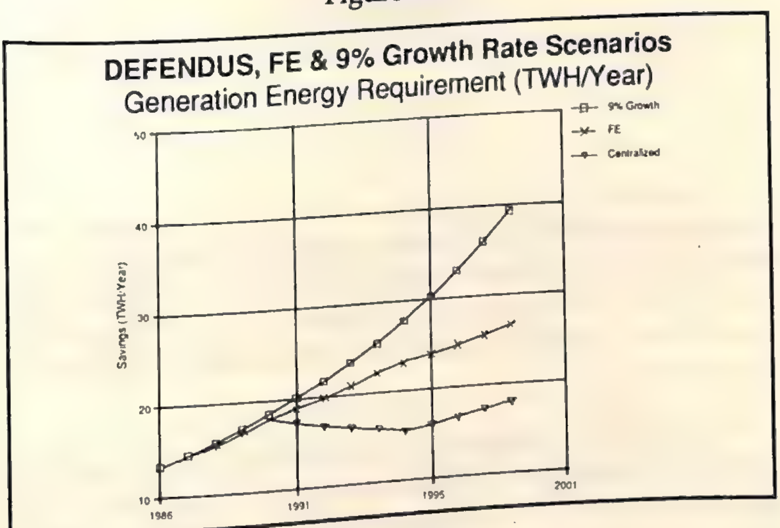


Figure 28

Actually, we have to consider two types of energy requirements (Figure 28) — a *frozen efficiency* requirement which indicates what would be the requirement had there been no efficiency improvement (i.e., if efficiencies are frozen

on the present level) and another requirement based on all the efficiency improvement and electricity substitution measures.

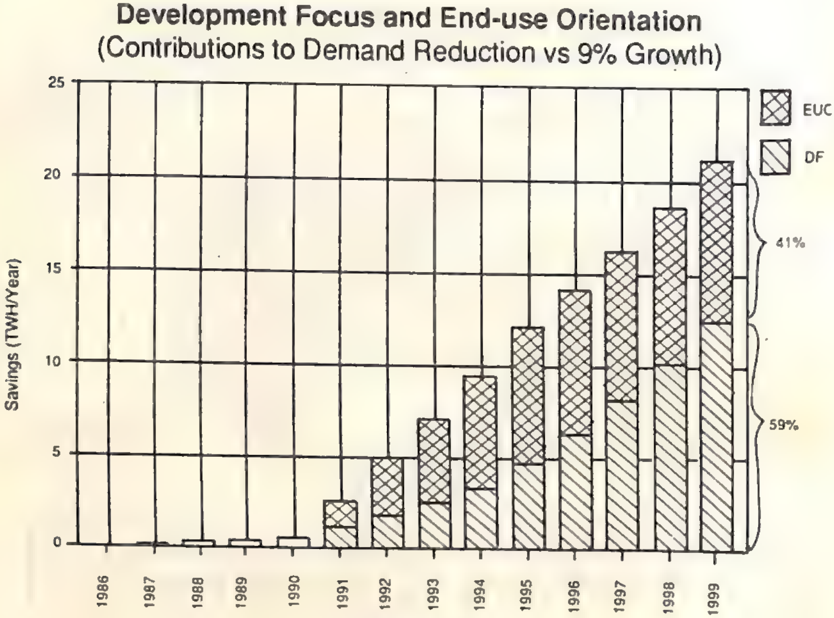


Figure 29

Consider the total reduction in the energy requirement as compared to a 9% growth rate projection (starting from the same base value as the DEFENDUS scenario). It turns out that 59% of the reduction comes only through the development-focus, and the other 41% is the result of efficiency improvements.

I urge you to ponder over this result. It embodies a very powerful message — *from an energy point of view, it is very expensive to keep poor people poor*. That is, it takes much less energy to address the energy needs of the poor than to ignore those needs. So, if you address poverty, for instance by electrifying homes, you will find that the total energy requirement goes down, not up. It means that if we make our energy plans people oriented, that in itself will reduce the

energy requirement tremendously. It seems, therefore, that for the sake of energy alone, we should tackle poverty.

Efficiency Improvements & Carrier Substitutions
(Saving = 7044 GWH/Year)

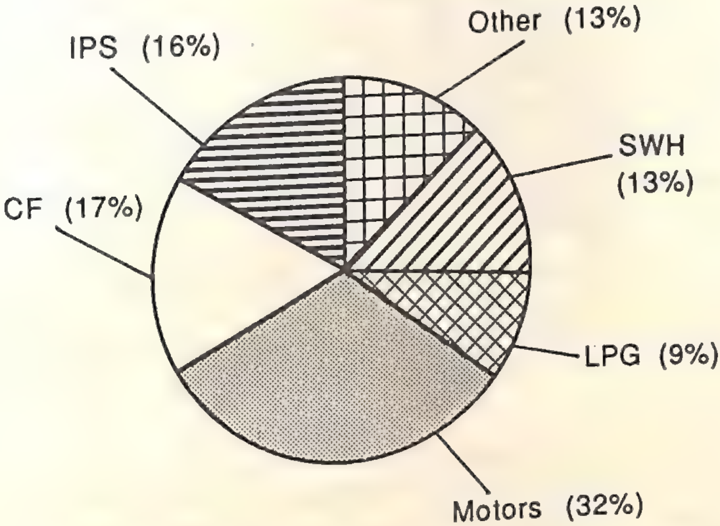


Figure 30

We can also disaggregate the reduction brought about by the various efficiency improvement and electricity substitution measures, i.e. motors, lights, etc. (Figure 30). It appears that all the measures have a role to play.

Figure 31 shows which sector accounts for how much reduction — 33% comes from HT sector, 32% from All-Electric-Homes etc. The main contributions come from the HT, AEH, irrigation pumpsets, and non-AEH categories of consumers.

Figure 32 shows what the Americans call the *bottom line* or the final set of numbers that we have to bear in mind — the LRPPP projection of 47.5 TWh compared to the DEFENDUS

Category-wise Savings
(Saving = 7044 GWH/Year)

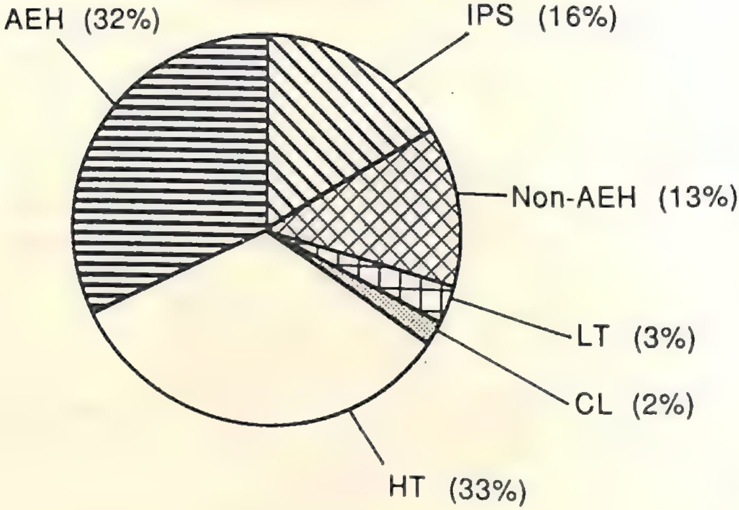


Figure 31

'Official' Electricity Plan (LRPPP)
vs
DEFENDUS Electricity Scenario (Centralized)

1986 Consumption= 7.554 TWH & Installed Capacity= 2.53 GW

		DEFENDUS	LRPPP	DEFENDUS/ LRPPP (%)
1986 Demand	(TWH)	10.431	12.013	87
1999 Consumption Requirement	(TWH)	14.646	38.729	38
1999 Generation Requirement	(TWH)	17.971	47.520	38
1999 Capacity Requirement	(GW)	3.976	9.397	42

Figure 32

requirement of 17.9 TWh which shows that the DEFENDUS scenario only requires 38% of the official scenario despite the fact that the official scenario does not try either to electrify all homes or to maximize employment generation through the LT industries or to energize all pumpsets. Even though the DEFENDUS scenario has taken on this enormous task and even though it is going to lead to a dramatic improvement in the quality of life of the people, the energy bill is only 38% of the official bill. Similarly, in terms of installed capacity, the LRPPP planners are asking for about 9,400 MW and the DEFENDUS requirement is only 4,000 MW, around 42%.

Official Electricity Plan (LRPPP)
vs
DEFENDUS Electricity Scenario (DES)

- LRPPP assumes growth rate in Energy Consumption (As a proxy for growth rate for Energy connections & for efficiency improvements).
- DES assumes growth rate in Energy Connections & efficiency improvements and derives growth rate in Energy Consumption.

Figure 32a

It is worth stressing at this stage a fundamental difference in the way the energy requirements in the future are arrived at (Figure 32A). The alternative DEFENDUS scenario assumes the growth rate in the connections of each category and in the energy consumption norm per connection of that category and *derives* the growth rate in energy consumption as a result. In contrast, the LRPPP projection (based on the conventional GROSSCON paradigm) *assumes* a growth rate in energy consumption as a proxy for both the growth rate in the connections and for the efficiency improvements.

DEFENDUS Scenario Calculation

E (0) = 2.53 GW, a = 0.71, g_G = 0.05 (5%), g_E = 0.0354 (3.54%)
& UCOP = Rs. 32,000/KW = ($ 2,000/KW),

Annual Investment required for Electricity Sector
= Rs. 287 crores/year = $ 180 million/per year
= One-third conventional approach
= Annual Plan allocation for Electricity Sector.

Figure 33

Incidentally, it appears that, if it follows the DEFENDUS paradigm, the electricity sector will be able to manage with what the State will make available. If, for instance, the State makes available 25% of its annual Plan, that would be enough to meet the DEFENDUS requirement. Thus, the electricity sector can adjust to the resource constraint. In contrast, the conventional paradigm proceeds as if there is no resource constraint, asks for five times more and then says resources are not available. After that the sector tries to carry on as it has been doing in the past, but cannot deliver the goods due to inadequate resources to support past patterns.

Common Objections to Conservation

Conservation OK, *But*

- Too expensive!
- Not much can be achieved with it!
- Consumers won't accept it!

Figure 34

We have laid a great deal of stress on efficiency improvements but I must warn you that there are a number of common objections to conservation. At the outset, the opponents of conservation say: "Conservation is alright for the wealthy industrialized countries, but we are so poor and we consume so little, how can anyone ask our people to conserve?" This objection ignores the difference between energy

services and energy consumption. Consurvation does not mean making do with less energy services but in achieving the same services with less energy consumption or a higher level of services with the same or even less energy. They also go on to say (Fig. 34): " Consurvation is O.K. but it is too expensive; even if it is not too expensive, you cannot achieve much with it, and finally consumers won't accept it...".

- Development = increase/improvement of Energy Services
- Energy Services = f (Useful Energy)
- Useful Energy = Efficiency x Energy input to Devices

Figure 35

This is where we must turn to the new paradigm or pattern of thinking. Development necessarily requires increase of energy services, but not necessarily an increase of energy consumption. What people want is more light, more warmth, etc. The level of energy services is determined by the magnitude of 'useful' energy; it does not depend merely on the quantity of input energy. That is, the level of energy services depends upon how much of the input energy is converted by the energy end-use device into what is useful. Thus, the useful energy depends upon two factors - the input energy and the efficiency of the end-use device. Both factors come into the picture. Why is this important?

Options for Increasing Energy Services

Option	Efficiency	Energy Input
1 (Conventional)	Constant	Increased
2 (Renewables)	Constant	Increased
3 (Conservation)	Increased	Constant

Figure 36

Because there are three well-known options for increasing energy services (Figure 36). The first one is the conventional paradigm of *supply-siders*—it says let your efficiencies remain as they are but ensure that you increase the supply

and input of energy. So it is a completely supply-biased approach. The second option is what many *environmentalists* are often guilty of: they also say increase the supply, but they distinguish themselves from the conventional supply-siders by insisting that the supply should come from renewable and environmentally benign sources of energy, and not from the conventional centralized and environmentally malign sources. But please note that they too have fallen into the supply trap of the conventional paradigm. Then there are the other extremists — the *conservationists* who say that you don't have to increase the amount of energy, all you need to do is to increase efficiency.

New DEFENDUS Paradigm

- Options (1), (2) & (3) are *extreme positions*
- Required --> Rejection of all three extreme positions
--> Holistic integration of above positions
- Increase of Energy Services through *Mix* of Efficiency improvements, decentralized and centralized sources

Figure 37

According to the DEFENDUS paradigm, all these are extreme positions (Figure 37) and we must reject all three of them. What we must achieve is a holistic integration of all these three options. That is a grand statement. How do you implement it? Everybody wants to be holistic, but how do you actually implement this holism. What we are asking for is an increase of energy services — the essential basis of development — through a *mix* of efficiency improvements, decentralized renewable sources and centralized sources. How do we work out the elements of this mix?

There is in fact a very simple technique called "least cost planning" (Figure 38) which is being increasingly adopted by the electricity utilities (as the electricity boards are known) in the United States. On the Y axis of a least cost curve is plotted the unit cost of the energy technology irrespective of whether it is a source of generation or a conservation meas-

Cost-Supply Curve
(Least-Cost Planning)

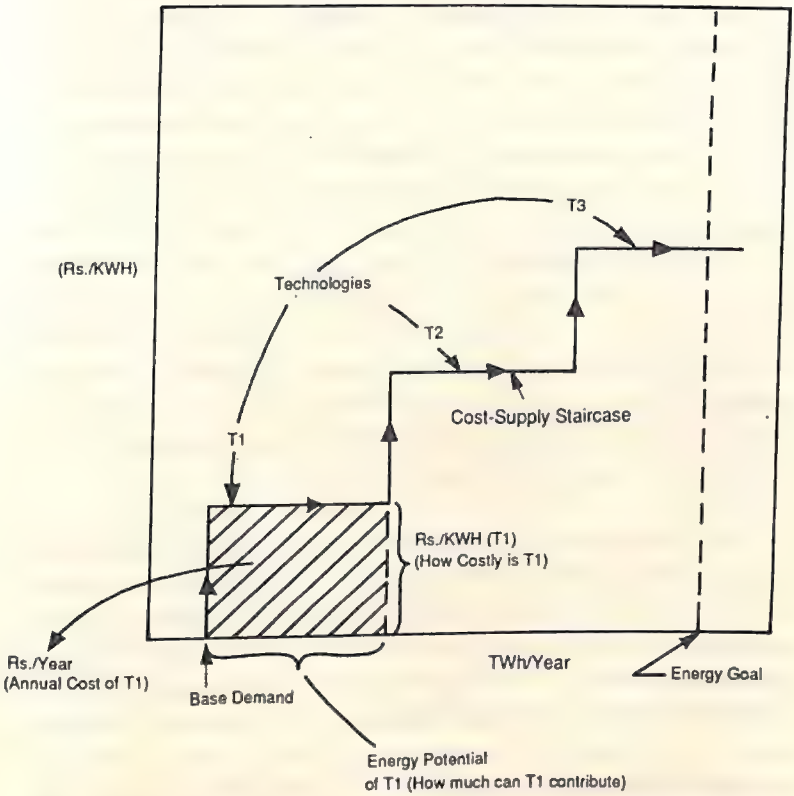


Figure 38

ure. Basically, what we are plotting on the Y axis is how much money we have to invest in order to save or to generate one unit of electricity. Please notice that in our new way of thinking, saving and generation are considered on equal terms — because saving a kWh is equivalent to generating one kWh. Actually, it is equal to generating more than one kWh because you save it at the consumer end and thereby avoid the transmission and distribution loss. So when you save a kWh at the consumption end, it is equivalent to generating more than one kWh.

For the least-cost DEFENDUS supply scenario for Karnataka, we have made a comparison of fifteen ways of saving

and generating electricity and we have ranked them according to increasing cost. Once you rank the technologies, then what is done in this least cost planning is to take the cheapest technology and make it the first element of the mix. Thus, in Figure 38, you start from the base demand and make technology T1, which is the cheapest technology, the first element of the mix. You see how far you can go with it and this depends on how much potential it has. When its potential is exhausted, you jump to the next technology, and so you climb this cost-supply staircase till you meet the energy requirement. All the technologies lying on the cost-supply staircase up to the energy requirement are the components of the supply mix that has to be used to meet the demand requirements. You don't play favourites at all. If, for instance, a conservation measure comes into the mix, you accept it. If it is too expensive, it rules itself out.

An important precaution has to be observed in setting up the energy goal at which the cost-supply staircase ends. Efficiency improvement and energy saving are like a cheque which you can cash only once. You can either cash it on the demand side or on the supply side. You cannot cash it on both the supply and demand sides. The preferable energy goal is the frozen efficiency energy goal which does not assume efficiency improvements so that even conservation measures become ordinary candidates for a place on the cost supply-staircase.

Comparison of all technologies on same terms

1. Same reference date
2. Start all technologies on reference date
3. Convert all pre-reference date cash flows using value of Rupee ($).
4. Convert all post-reference date cash flows using discount rate
5. Do not ignore Gestation Period.
6. Use either nominal or real discount rate, but not both.
7. Present all results as a function of discount rate.
8. Compare technologies on the basis of cost-benefit ratios.
   (Unit Cost of Power: UCOP = Rs/KW or $/KW &
   Unit Cost of Energy: UCOE = Rs/KWH).

Figure 39

Of course, the competition between technologies must be on the same terms. This caution is important because careful scrutiny reveals all sorts of hidden subsidies for the centralized sources. Some of these technical details to insure comparison on equal terms are shown in Figure 39.

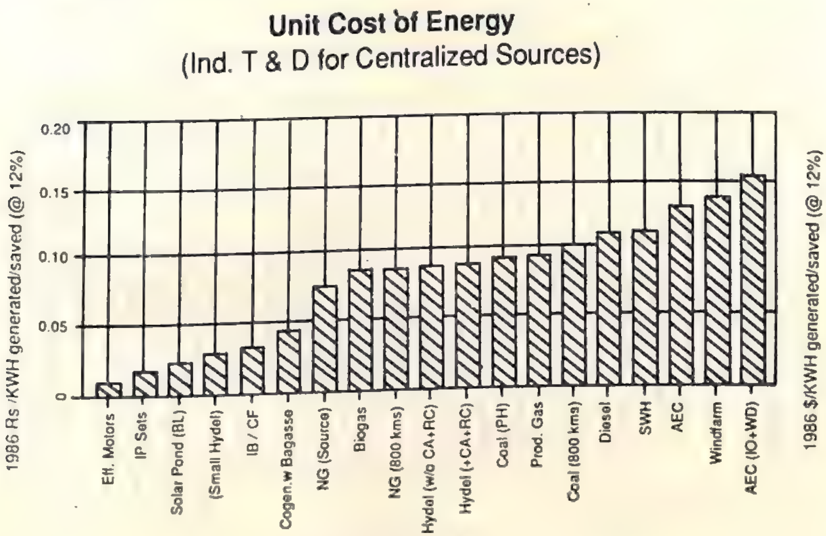


Figure 40

The ranking of the energy technologies according to increasing cost is shown in Figure 40 in which each bar represents a technology — either of saving or of generating electrical energy - and the height of the bar represents the cost per kWh. We see that at the extreme right are the large-scale centralized sources with nuclear power coming out as the most expensive source, efficiency improvements are on the left and somewhere between come the decentralized sources. Please notice that the most expensive technologies have the most powerful lobbies behind them — thus the centralized technologies have ministries, decentralized technologies have a department and conservation has had until recently only an advisor. The budget for each one of the centralized sources is of the order of hundreds of crores, the budget for the decentralized ones, a few tens of crores and for conserva-

tion, probably less than a crore. Since it is primarily the centralized sources that have been implemented thus far, it appears that what our government has been following is not the least-cost planning approach but *maximum-cost planning* approach.

Unit Cost of Power
(Ind. T & D for centralized Sources)

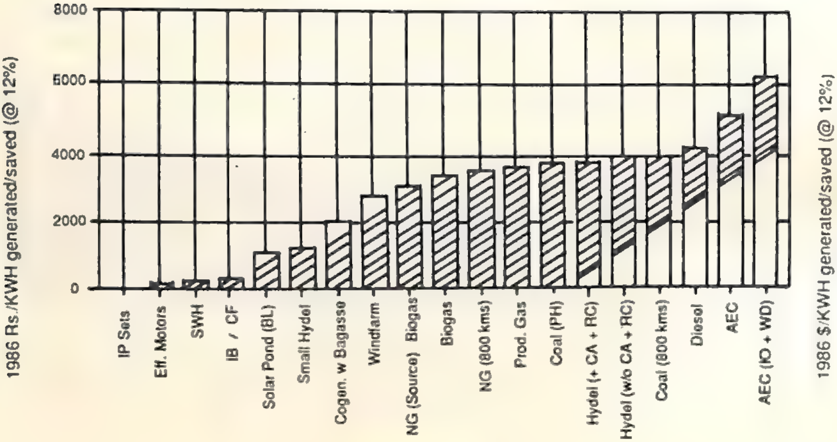


Figure 41

Roughly the same conclusion emerges from a ranking of the costs of installed capacity (Rs/kW).

On the basis of the ranking of costs of energy technologies, the least-cost DEFENDUS supply curve for Karnataka has been constructed (Figure 42). It shows the least-cost DEFENDUS mix of technologies required to meet the frozen efficiency goal for Karnataka. Motors are the cheapest technology, and therefore, they come as the first element of the mix, then improvement of irrigation pumpsets, followed by small hydel, compact fluorescent lamps, cogeneration from bagasse fuel in sugar factories, biogas, producer gas and then natural gas. It turns out that we can reach the energy goal without invoking nuclear power.

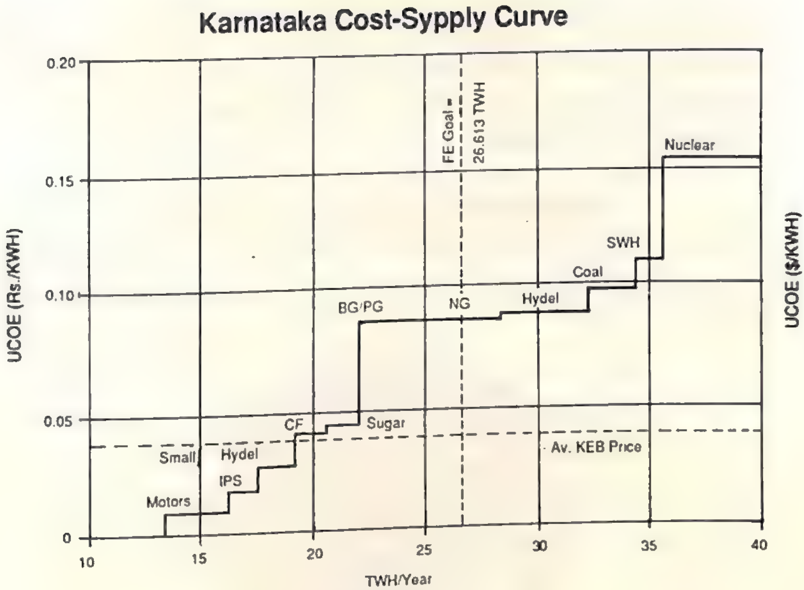


Figure 42

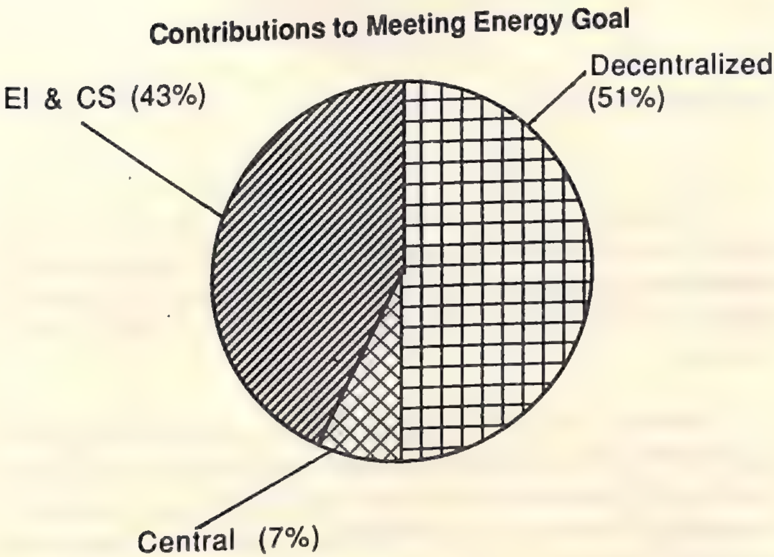


Figure 43

We find that 43% of the *extra* energy required comes from efficiency improvements and 51% from decentralized

sources consisting of renewables. This result has come automatically out of least-cost planning; it was not produced to please the environmentalists, though it certainly will. And the least-cost mix has avoided new additions of the harsh centralized technologies.

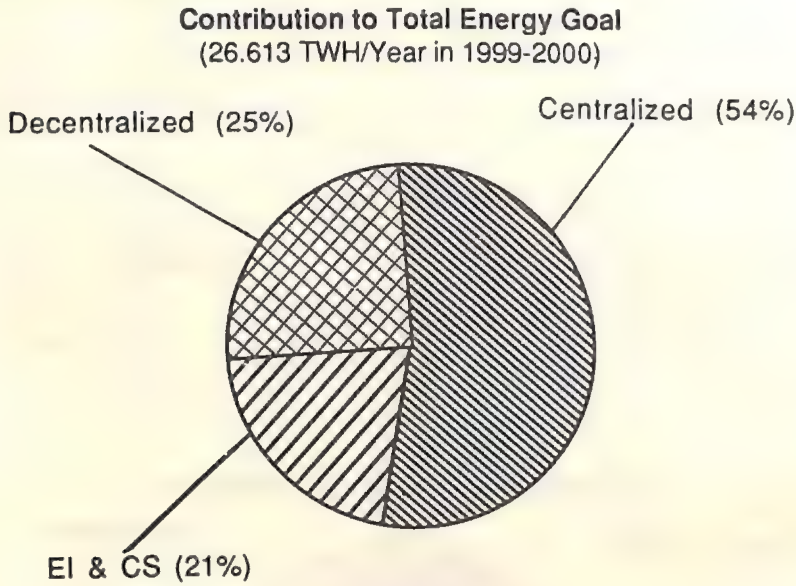


Figure 44

If instead one considers the contributions to the *total* energy—and not merely the extra energy—it turns out that centralized sources have a much larger role (Figure 44) because all the initial demand is being met from these sources.

Instead of the least-cost mix, the conventional paradigm starts with nuclear, coal and hydel and leads to what we may call "maximum-cost planning". Since the area under a cost-supply curve [(Rs/kWh)*(kWh/year)] yields the annual cost (Rs/year) for the mix of technologies defined by the curve, we can compare the cost of the DEFENDUS least-cost mix with the cost of the official maximum-cost plan. It turns out that the DEFENDUS supply scheme is only about one-

third of the cost of the centralized supply. At one third the cost, the energy goal can be met whilst providing more services to the people. Thus, the area between the maximum-cost and least-cost curve (Figure 45) represents the squandering of public funds that results from adopting, not the least-cost mix, but an arbitrary mix that has obviously been arrived at by considerations other than cost. What these other considerations are I leave to your imagination but there are many vested interests that derive advantages from maximum-cost planning and large projects.

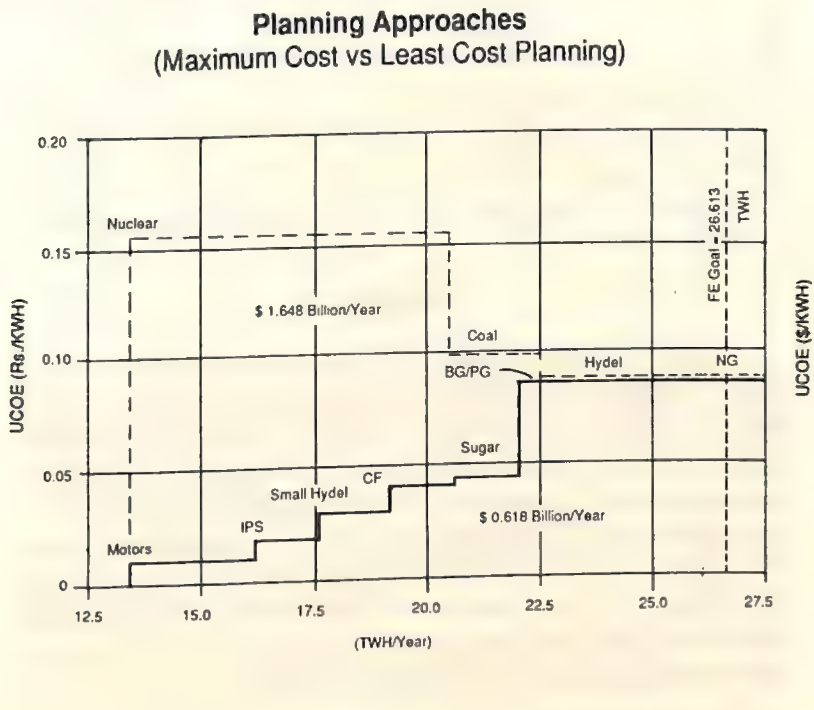


Figure 45

Least Cost Curve

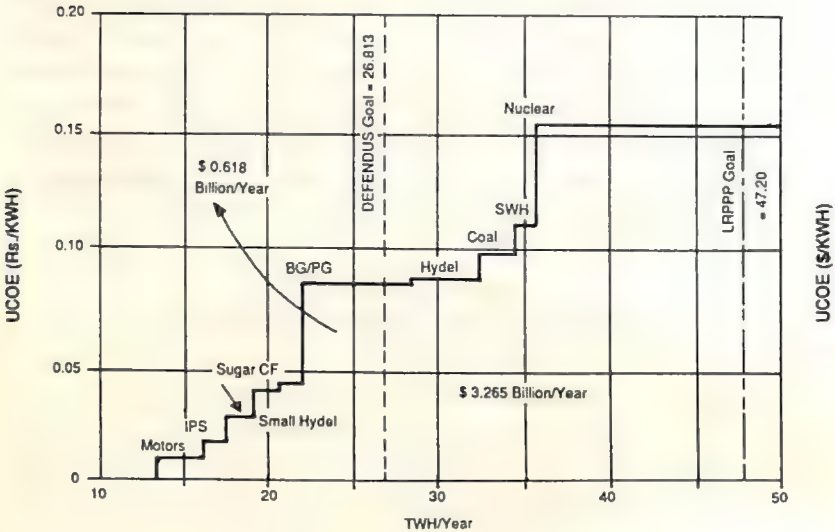


Figure 46

Please note from Figure 45 that as the energy requirement increases, i.e. as the demand increases, the more we are forced to go in for the environmentally malign and harsh technologies. As the demand goes down, it becomes possible to avoid some of these harsh technologies. So, the technologies that must be invoked are very much dependent upon the magnitude of the demand target. This is the reason why the demand targets are often purposely pushed to high values, so that they justify some of the harsh technologies that would not come in for lower demand targets.

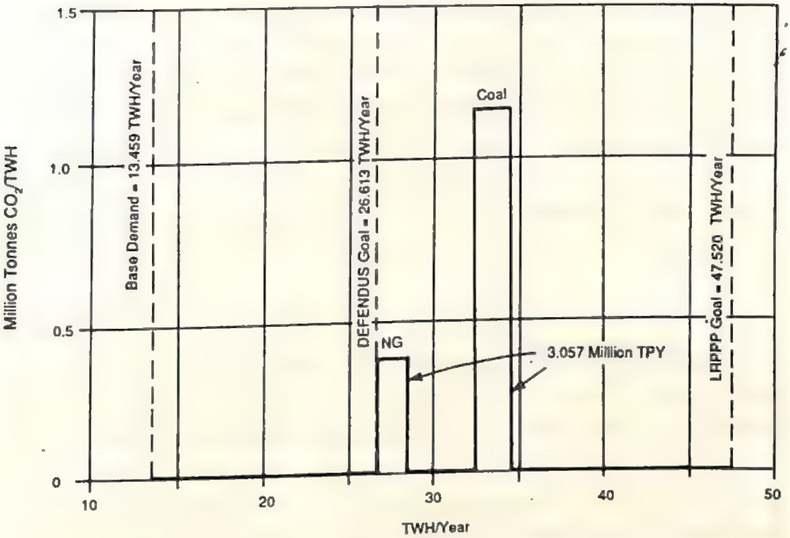


Figure 47

It can also be shown that the global environmental impacts measured for example by the CO_2 emissions are less for the DEFENDUS scenario compared to the maximum-cost scenario (Figure 47).

We have also shown that the DEFENDUS supply scheme achieves energy goals quicker.

In fact, we have confirmed a feeling that many of you have had for a decade that *alternative scenarios based on efficiency improvements and decentralized sources are cheaper, quicker and more environmentally benign*. They score on all counts. Hitherto, this statement has been a statement of faith; now, we have hard numbers to back the statement - this is what we have achieved. It is not any longer a question of dismissing emotional hand-waving arguments. Now, the hard numbers and facts have been put on the table — one third the cost, quicker and more environmentally benign. It is becoming in-

creasingly difficult in the context of the serious capital-scarcity crisis and of projects being deadlocked in environmental conflicts for the decision-makers to ignore the DEFENDUS alternative anymore.

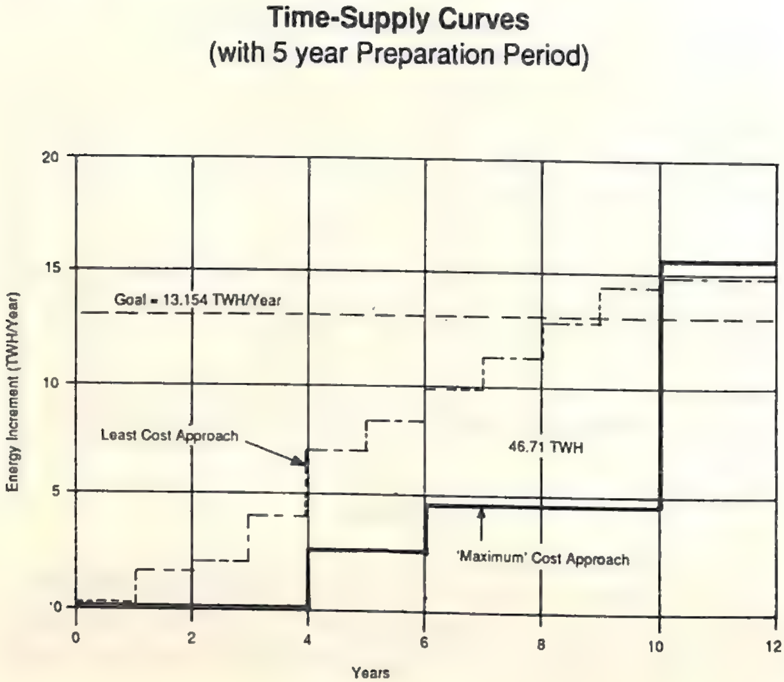


Figure 48

Other Advantages of DEFENDUS Scenario

- Shorter Gestation Time
- More Environmentally Benign
- Massive Employment-Generating Programme (14.5 Million CF Lamps, 498,000 SWH, 535,000 FFV + HDPE Retrofits for IP sets for 1986-87 consumers)
- Rural Employment Generation + Village self-reliance (About 26,000 RECs)
- Simultaneous Industrial Modernization
- Dramatic Improvement In Quality of Life

Figure 49

The DEFENDUS scenario has other advantages (Figure 49). It is a massive employment generating programme - over 10 million compact fluorescent lamps have to be produced, distributed and connected, about half a million solar water heaters have to be manufactured and installed, half a million irrigation pumpsets to be retrofitted, and so on. Think of all the industries that are required for these products and think of the enormous number of technical people that will have to implement this. Karnataka will become a hub of activity. Then, there is rural employment generation and village self-reliance because of the large number of rural energy centres.

Finally, there is the challenge of simultaneously achieving industrial modernization (efficient motors etc.) along with tackling the power problem. All these days, industrial circles have been proceeding on the assumption that they are the natural allies of the electricity sector. But what the electricity sector has been doing all these years is to keep these industries inefficient and use public funds for increasing the supply of energy. If, however, these funds are invested in efficiency improvements in industry, then industry can be modernized simultaneously with bridging the demand-supply power problem. And finally, the development focus of the DEFENDUS scenario corresponds to a dramatic improvement in the quality of life.

The DEFENDUS scenario is so obviously superior that it (or some variant of it) should be chosen if rationality prevailed. But, energy decision-making is not done on the basis of rationality alone; there are powerful vested interests that have grown along with the electrical supply industry. Hitherto, these vested interests have ensured that only supply-biased strategies are implemented. And, the financial and aid institutions have gone along with these supply-biased approaches partly because the opposing arguments have been of the hand-waving variety without numbers to back them.

But, now the supply lobby does not have the capital to carry through its exorbitantly expensive schemes. Further, the funders have an alternative scenario on the table which will be worked out in ever-increasing detail. Will these funding institutions be able to resist and reject the more cost-effective solutions that are also more environmentally sound and in the interests of the people? The deciding factor may well turn out to be the fact that development-focussed end-use-oriented scenarios are of the future and the conventional plans belong to a vanishing present. And, *the future may be difficult to implement, but the present is impossible to sustain.*

If opportunities for efficiency improvements are systematically identified and exploited wherever cost-effective, the magnitude of energy demand can come down sharply. In this context, energy supplies need not become a constraint on growth.

A Thought Experiment

$$E\,(\text{TOTAL}) = \text{SUM}\,[(\text{ACTIVITY LEVEL})]_i^{\bullet}\,(\text{SPECIFIC ENERGY})_i$$

ACTIVITY LEVELS --> WESTERN EUROPE IN 1970s
(E.G., 320 kg STEEL/CAPITA/YEAR)
SPECIFIC ENERGIES --> MOST EFFICIENT END-USE TECHNOLOGIES (COMMERCIAL/NEAR COMMERCIAL)
(E.G., ELRED/PLASMAMELT @ 10 GJ/TONNE)

RESULT --> 1 KW/CAPITA FINAL ENERGY vs
0.9 KW/CAPITA IN 1980

Figure 50

In fact, a thought experiment shows (Figure 50) that if the most energy-efficient technologies that are either commercial today or near commercialization are deployed for all activities, then we can achieve a level of energy services or activities corresponding to Western Europe in the 1970s with only a slight increase in their per capita energy requirement.

Hence, *it is not the magnitude of energy that is a constraint on the achievement of significantly higher standards of living.* Of course, this process cannot go on indefinitely.

BUT EVEN THIS PROCESS CANNOT CONTINUE WITHOUT LIMIT!
ULTIMATELY
AS GANDHI SAID:

"THE WORLD HAS ENOUGH FOR EVERYONE'S NEED,
BUT NOT ENOUGH FOR EVERYONE'S GREED!"

Figure 51

Ultimately, we must accept what Mahatma Gandhi said: "The world has enough for every man's need, but not enough for everyone's greed!"

In conclusion, the main submission of my lecture is that energy can be forged into an instrument for development. But, for that to happen, energy planning must start from people, particularly the poor, their basic needs, the energy services that must be provided to satisfy these needs, the energy activities corresponding to these services, the efficient end-use devices required for these activities. Only after all this should the task of matching supplies to the lowered demand be placed on the agenda. If this perspective is adopted, energy futures compatible with the achievement of sustainable development are achievable and within our grasp. The choices that are proposed require imaginative political leadership. But, they represent far less difficult and hazardous options for this leadership than those demanded by the conventional approaches to the world's energy future. Above all, *this energy future is more a matter of choice than of destiny.*

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परिसर